From Field to Fish: Tracking Changes in Diet on Entry to Two Medieval Friaries in Northern England

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Abstract

Members of religious orders during the later medieval period in Britain were expected to adhere to strict rules governing their daily lives which restricted their consumption of meat. This study aims to investigate whether this switch to a 'religious diet' can be isotopically detected in presumed religious individuals upon their entry into a religious order during adolescence. Secondary aims of this study include: 1) a comparison of the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope values between individuals with and without diffuse idiopathic skeletal hyperostosis (DISH); and 2) to compare the mean values of the sites analyzed with geographically and temporally related sites from previously published studies. To achieve these aims, $\delta^{13}C$ and $\delta^{15}N$ analysis of third molar incremental dentine collagen and bulk rib bone collagen was undertaken on ten presumed religious individuals: five from the Carmelite friary at Priory Close, Northallerton, founded in AD 1356, and five from the Friars of the Sack-turned-Carmelite friary at Clavering Place, Newcastle-upon-Tyne, founded in AD 1266. Twelve contemporaneous faunal samples were also analyzed to provide an isotopic baseline. The $\delta^{13}C$ and $\delta^{15}N$ profiles of all individuals from both sites in this study increased from the beginning of the formation of the third molar at c. 8.5 years to its completion at c. 23.5 years indicating a shift during adolescence from a largely terrestrial mixed diet to one that contained a significant amount of animal and marine protein. Individuals exhibiting skeletal pathology indicative of DISH were found to have individual $\delta^{13}C$ and $\delta^{15}N$ values that were elevated above the means for each site, and the mean rib collagen $\delta^{13}C$ and $\delta^{15}N$ values at Priory Close and Clavering Place were in line with published data from other later medieval religious sites in northeastern England. This study provides evidence for a shift in diet experienced by members of religious orders during adolescence and lays the foundation for future studies of dietary changes at different religious institutions.

Key words: carbon, nitrogen, stable isotope analysis, palaeodiet, DISH, Carmelite, Friars of the Sack

Declarations of interest: none

1 Introduction

Monasticism played an integral and pervasive role in Christianity in England from the late 6th century AD to the Dissolution of the monasteries in AD 1536-41 (Burton 1994, 1). The term 'monasticism' typically evokes an image of cloistered monks segregated from society. However, there are other types of religious orders that do not follow this stereotypical pattern, namely the mendicant orders of friars. Whilst both followed strict rules governing their daily lives, even so far as dictating the components of their diet, friars differed from monks in that they did not own property and had an active mission to the laity, thus requiring them to settle in urban areas where they could beg for their livelihood and fulfill their mission (Burton 1994, 1, 125). Due to their predominantly urban settings, friaries have suffered more destruction than rural monasteries and so are relatively rare in the archaeological record (Greene 1992, 24). Two sites in northern England—a Carmelite friary in Northallerton and a Friars of the Sack-turned-Carmelite friary in Newcastle-upon-Tyne—both of which yielded human remains, provide an opportunity to gain an insight into the dietary habits of likely medieval friars, particularly in relation to whether changes in diet occurred upon entry to the friary (Figure 1).

1.1 Aims of Study

The primary aim of this study is to determine whether an isotopically detectable change in diet occurs in individuals entering a religious order. This will be achieved by analyzing incremental dentine collagen $\delta^{13}C$ and $\delta^{15}N$ profiles of third molars of presumed religious individuals. Secondary aims include: determining if the diet of the individuals analyzed is comparable with that of individuals from temporally and/or geographically similar published sites through comparing bulk rib bone collagen $\delta^{13}C$ and $\delta^{15}N$ values; and exploring whether there is a link between these isotopic values and pathology purported to have a link with diet, namely diffuse idiopathic skeletal hyperostosis (DISH).

1.2 Orders, Rules, and Diet

With their origin as hermits on Mount Carmel in the Holy Land, the Carmelites were forced to relocate away from this area due to unrest, and by AD 1242 had established settlements in England (Andrews 2006, 14). The Rule of St. Albert acted as the basis upon

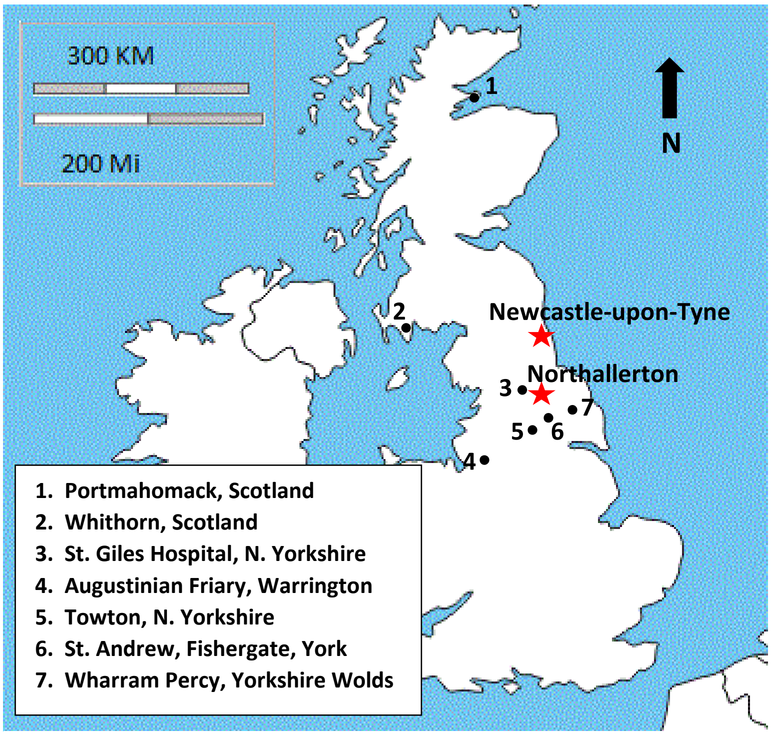

Figure 1. Map of Britain showing sites mentioned in this study. *The red stars denote the locations of the two sites being analyzed (Clavering Place in Newcastle-upon-Tyne and Priory Close in Northallerton). The numbered sites provide a comparison.*

which the Carmelite friars led their daily lives. Concerning diet, the Albertine version (dating to between AD 1206 and 1214) instructed the friars, "You are always to abstain from meat, unless it has to be eaten as a remedy for sickness or great feebleness" (Edwards 1973a, 87). Soon after, in AD 1247, the Rule was mitigated slightly to allow consumption of meat while on journeys to avoid giving trouble to the friars' hosts (*ibid.*).

Most likely named for the humble, sack-like cloth that they wore, the Friars of the Sack were only in existence for a short period of time (Andrews 2006, 177). Founded in Provence in the 1240s AD, the order was forced to dissolve less than 40 years later as the result of the sanctions decreed by the Second Council of Lyons in AD 1274 (*ibid.*, 173, 175). The Friars of the Sack followed the Rule of Augustine, but, unfortunately, no copy of the Rule specific to the Friars of the Sack has yet been identified (Andrews 2006, 186). However, other extant documents attest to the fact that, similar to the Carmelites and religious Orders in general, meat was excluded from their diet, and the friars observed fasting for long periods of time (*ibid.*).

This comprehensive proscription of meat throughout religious Orders resulted in the widespread consumption of fish as a substitute (Serjeantson and Woolgar 2006). In fact, even among lay people, an isotopic shift to a diet containing more marine protein during the later Medieval period in England and Scotland has been noted in multiple studies (Barrett and Richards 2004; Müldner and Richards 2005; Müldner and Richards 2007a; Curtis-Summers *et al.* 2014). Barrett *et al.* (2004) offer several explanations for this increase in fish consumption, citing a general, large-scale increase in fishing during this time period to meet the demands of growing urban populations. Here, however, due to the presumed religious individuals under discussion, we focus on one of the contributing factors proposed by Barrett *et al.* (2004), namely adherence to church fasting regulations.

It is no secret, however, that as the Middle Ages progressed, religious individuals, including friars, became lax in following their respective Rules, especially in regard to the austere dietary specifications. By the late 13th century, descriptions of overweight friars even made their way into popular literature such as Chaucer's translation of Jean de Meun's *Le Roman de la Rose* (Benson 1987, 765, lines 7459-7463):

> So ben Augustyns and Cordyleres,

And Carmes, and eke Sacked Freeres,
And alle freres, shodde and bare
(Though some of hem ben great and square),
Ful hooly men, as I hem deme;

The lines of the poem (provided above) list four major mendicant orders of friars (Augustinians, Franciscans, Carmelites, and Friars of the Sack), and it accuses some of them of being "great and square", which translates into modern English as "big and fat" (Andrews 2006, 64). By the 15th century, even the Carmelites requested further mitigation of their austere Rule, and by AD 1488, it was declared that meat could be eaten throughout the order on Mondays (Edwards 1973b, 30). In fact, by this time, the monastic diet is typically equated with that of the upper-class (Harvey 1993, 34).

1.3 Stable Isotope Analysis

Nearly 40 years ago, one of the first archaeological studies to apply stable carbon isotope analysis of bone collagen demonstrated that differences in $\delta^{13}C$ values could be measured in individuals who consumed non-maize, C_3 plants *versus* those who consumed maize, a C_4 plant (Vogel and van der Merwe 1977). Since then, both $\delta^{13}C$ and $\delta^{15}N$ values have been utilized as reliable indicators for palaeodietary reconstruction in various archaeological settings. The $\delta^{13}C$ values provide information regarding the consumption of plants that use different photosynthetic pathways. C_3 plants, including rice, wheat, and potato, have lower $\delta^{13}C$ values than C_4 plants which include maize, sorghum, and sugarcane (Tauber 1981; Wang *et al.* 2012). Additionally, the $\delta^{13}C$ values may also be used to elucidate the contribution of marine protein versus terrestrial protein to the diet, with higher $\delta^{13}C$ values providing evidence of marine protein consumption (Schoeninger and DeNiro 1984). The $\delta^{15}N$ values provide information regarding relative trophic level, with each successive trophic level increasing the $\delta^{15}N$ value by approximately 3‰, although increases of up to 6.5‰ have been noted (Schoeninger and DeNiro 1984; Sponheimer *et al.* 2003). As with $\delta^{13}C$ values, $\delta^{15}N$ values also provide information regarding marine *versus* terrestrial protein, with higher values indicating a higher proportion of marine protein consumption (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984).

Dietary reconstruction using carbon and nitrogen isotopic analysis is possible based on the premise that the isotopic composition of an individual's body is reflective of the isotopic composition of that individual's diet (DeNiro and Epstein 1978, 1981). The δ^{13}C and δ^{15}N values of an individual's collagen are representative of that individual's dietary protein consumption (Jim *et al.* 2004) and not of diet as a whole. Once consumed, the dietary protein components (i.e. amino acids) are preferentially routed to collagen (Lee-Thorp 2008). The characteristic isotope values that allow a reconstruction of diet (e.g. an increase in δ^{15}N at each trophic level) are the result of the isotopic fractionation that occurs as these amino acids undergo numerous biochemical reactions as they become incorporated into the collagen (Macko *et al.* 1987; Hare *et al.* 1991; Makarewicz and Sealy 2015). Before any conclusions can be drawn in regards to dietary reconstruction, it is essential to determine the δ^{13}C and δ^{15}N values of an individual's presumed baseline diet (e.g. contemporaneous faunal samples from the site), as there are multiple factors that may alter the expected baseline levels (Makarewicz and Sealy 2015). For example, herbivores in arid environments are noted to have higher δ^{15}N values than expected (e.g. Murphy and Bowman 2006; Hartman 2011), and the crop husbandry practice of manuring increases the δ^{15}N of the crops and consequently the δ^{15}N of the herbivores that graze on the crops (Bogaard *et al.* 2007; Fraser *et al.* 2011; Treasure *et al.* 2016; Gron *et al.* 2017). Not taking this critical information into consideration will cause flawed inferences about an individual's diet, especially when considering relative trophic levels.

Bone collagen constantly remodels, or turns over, throughout an individual's life, continuously incorporating δ^{13}C and δ^{15}N from the diet. Bulk bone collagen samples are thus representative of an individual's average dietary protein intake over a period of time. The length of time represented is dependent upon which bone is sampled (Bell *et al.* 2001; Hedges *et al.* 2007) as well as the individual's age (Wild *et al.* 2000; Valentin 2002), such that a sample from a juvenile, having a rapid turnover rate, will represent a shorter time period, and that of an adult, with a slow turnover rate, will represent a much longer time period. This can be contrasted with tooth enamel and dentine, which, once formed, do not remodel and consequently retain the isotopic signals from the time they were formed (Hillson 2005, 185). For example, deciduous second molar dentine, which forms from c. 16-24 weeks *in utero* until c. 3 years of age, has been shown to have higher δ^{13}C and δ^{15}N values than the bulk rib collagen values in the same individual (Richards *et al.* 2002). This is due to the trophic level effect of nitrogen as well as a ‘carnivore effect’ of carbon, both of which result from an infant being a trophic level above its mother throughout the time of breastfeeding (*ibid.*).

Greater detail was achieved when discreet sections of individual teeth (crown, cervical, and apical root sections) were analyzed for $\delta^{13}C$ and $\delta^{15}N$ (Fuller *et al.* 2003). This incremental approach takes advantage of the fact that the teeth form in layers, beginning from the cusps of the crown and completing at the root tip (Hillson 2005, 210). Subsequent studies refined the technique further and confirmed the reliability of analyzing horizontal tooth increments as small as 1mm; thus, allowing the recreation of individual isotopic life histories corresponding to the time of the years of formation of the tooth (Beaumont *et al.* 2013; Beaumont *et al.* 2014).

The high temporal resolution attainable with this technique has subsequently led to more detailed studies about weaning because it is well-suited to identifying transient changes in diet that would otherwise go unnoticed in conventional osteological analyses (e.g. Henderson *et al.* 2014; Sandberg *et al.* 2014). The advantages of this method have also been applied to other issues, such as investigating maternal and child health during the perinatal period (Beaumont *et al.* 2015), identifying migrant individuals from a cemetery based on differences in their diets (Beaumont *et al.* 2013), revealing short-term food sources in the event of adverse environmental conditions (Montgomery *et al.* 2013), and identifying patterns associated with nutritional and physiological stress (Beaumont and Montgomery 2016).

Carbon and nitrogen stable isotope analysis of incremental dentine is therefore well-suited to detect the differences in diet that may have been experienced by individuals entering a religious order. Both possibilities, whether the more austere version containing predominantly fish, or the more lavish version containing many varieties of rich foods including an excessive amount of animal protein, should show a marked change in an individual’s dentine isotopic profile upon admission to the mendicant order. Unless the individuals joining the friary came from upper-class families, this switch to a friar diet should be visible because during this time period, the only people other than the religious who could attain a diet so rich in protein were those few in the upper strata of society (Woolgar 2006, 101).

1.4 Diffuse Idiopathic Skeletal Hyperostosis (DISH)

Diffuse idiopathic skeletal hyperostosis (DISH) is a condition distinguished by a ‘flowing candlewax’ ossification of the anterior longitudinal spinal ligament as well as entheseal changes at extra-spinal sites, notably the proximal ulna, the patella, and posterior calcaneus (Figure 2; Rogers and Waldron 1995). DISH can be diagnosed in

Figure 2. Lateral and anterior views of sixth to twelfth thoracic vertebrae of Skeleton PC-59 from Priory Close. *From left: right lateral view, anterior view, and left lateral view. Note the 'flowing candlewax' appearance of the osteophytes on the right side of the vertebral bodies typical of DISH. (Photo Anwen Caffell for Archaeological Services Durham University)*

archaeological skeletons when the hyperostosis affects at least three vertebrae, when this hyperostosis is confined to the right-hand side of the thoracic vertebrae, and when there is evidence of extra-spinal calcification or ossification of ligaments and/or entheses (Rogers and Waldron 2001). It is more common in males than females, and its prevalence tends to increase with age (Vaishya *et al.* 2017). Although its etiology remains unknown, DISH has been linked to obesity (e.g. Kiss *et al.* 2002; Mader and Lavi 2009; Pillai and Littlejohn 2014; Kacki *et al.* 2018), and patients with DISH are more likely to be affected by metabolic syndrome (e.g. Mader *et al.* 2009; Pariente-Rodrigo *et al.* 2017), a condition encompassing disturbed glucose and insulin metabolism, obesity and abdominal fat distribution, hypertension, and dyslipidemia (Mader *et al.* 2009). An association between DISH and type 2 diabetes is a debated issue, as several studies have found an association between the two (e.g. Kiss *et al.* 2002; Mader and Lavi 2009; Pillai and Littlejohn 2014), while others have not (e.g. Mata *et al.* 1997; Sencan *et al.* 2005).

A link between DISH and the monastic lifestyle was initially proposed when it was noted that 8.6% of the assumed religious burials at Merton Priory demonstrated pathological changes consistent with DISH—a percentage considerably higher than the 2.8% prevalence of DISH in a modern population (Julkunen *et al.* 1971; Waldron 1985). Considering the associations between DISH, obesity, and diabetes discussed in clinical literature, it was therefore postulated that the historically documented rich and plentiful diet of medieval religious individuals, together with their sedentary lifestyle, both leading to obesity and presumably type 2 diabetes, may have played a role in inducing DISH in the canons at Merton Priory (Waldron 1985; Rogers and Waldron 2001).

If there is an association between the monastic diet (i.e. a diet containing a substantial amount of animal and/or marine protein) and DISH, the δ^{13}C and δ^{15}N values of affected individuals should be elevated due to this increased protein consumption when compared with the general population. Although not statistically significant, a number of studies have demonstrated that there is a visual trend for the δ^{13}C and δ^{15}N values of those individuals with DISH to plot higher than those without the condition (e.g. Müldner and Richards 2007b; Spencer 2008; Quintelier *et al.* 2014; Kacki *et al.* 2018).

2 Materials and Methods

Despite most of the individuals recovered from Priory Close and Clavering Place having since been reburied, a selection of teeth and rib fragments were collected from each individual prior to their reburial and retained for future analysis. Because of this, the selection criteria for inclusion in this study was limited to those individuals for whom an M3 was available for analysis. Despite this limitation, the predominantly male demographic profile, as well as burial location within the friary, suggest that the majority may have been friars. In addition, twelve long bone samples from contemporaneous domestic fauna were chosen to establish the faunal baseline at the sites.

2.1 The People and Places

2.1.1 Priory Close

The Carmelite friary in Priory Close, Northallerton, North Yorkshire, was founded in AD 1356 (Knowles 1940, 114), and it remained in use until the Dissolution in AD 1538 (Randerson *et al.* 2015). The site was excavated in 2006 by Archaeological Services, Durham University, recovering eight skeletons (*ibid.*). These individuals were buried in the presumed cloister alley, a location considered in different religious orders to demonstrate a distinct zoning of age, whether juvenile or other age groupings (Gilchrist and Sloane 2005, 68). Of the eight excavated skeletons, one individual, estimated to be an adolescent of 12-14 years of age (Caffell 2007), was recovered from the southern cloister alley, while the remaining seven individuals were recovered from the eastern cloister alley (Figure 3; Randerson *et al.* 2015). All individuals from the latter location, five of whom were selected for analysis, were adult males of at least 25 years of age, except possibly Skeleton (Sk.) PC-52 whose sex was unable to be determined but who was the oldest individual (Caffell 2007; Randerson *et al.* 2015), suggesting that these seven individuals may be the friars themselves. This conclusion is supported by archival evidence from the post-medieval Carmelite friary in Aalst, Belgium, indicating that the inhabitants of the friary were preferentially buried in the cloister alley (Quintelier *et al.* 2014). One individual from Priory Close (Sk. PC-59) had skeletal pathology diagnostic of DISH, while two others (Sks. PC-42 and PC-52) displayed changes typical of DISH but could not be diagnosed due to poor skeletal preservation: Skeleton PC-42 had osteophytes on the right side of the lower thoracic spine, but the areas typical of extra-spinal enthesophyte formation were not preserved

(Caffell 2007). Conversely, Sk. PC-52 had bridging of the sacroiliac joint as well as extra-spinal entheseal changes, however the spine was poorly preserved (*ibid.*).

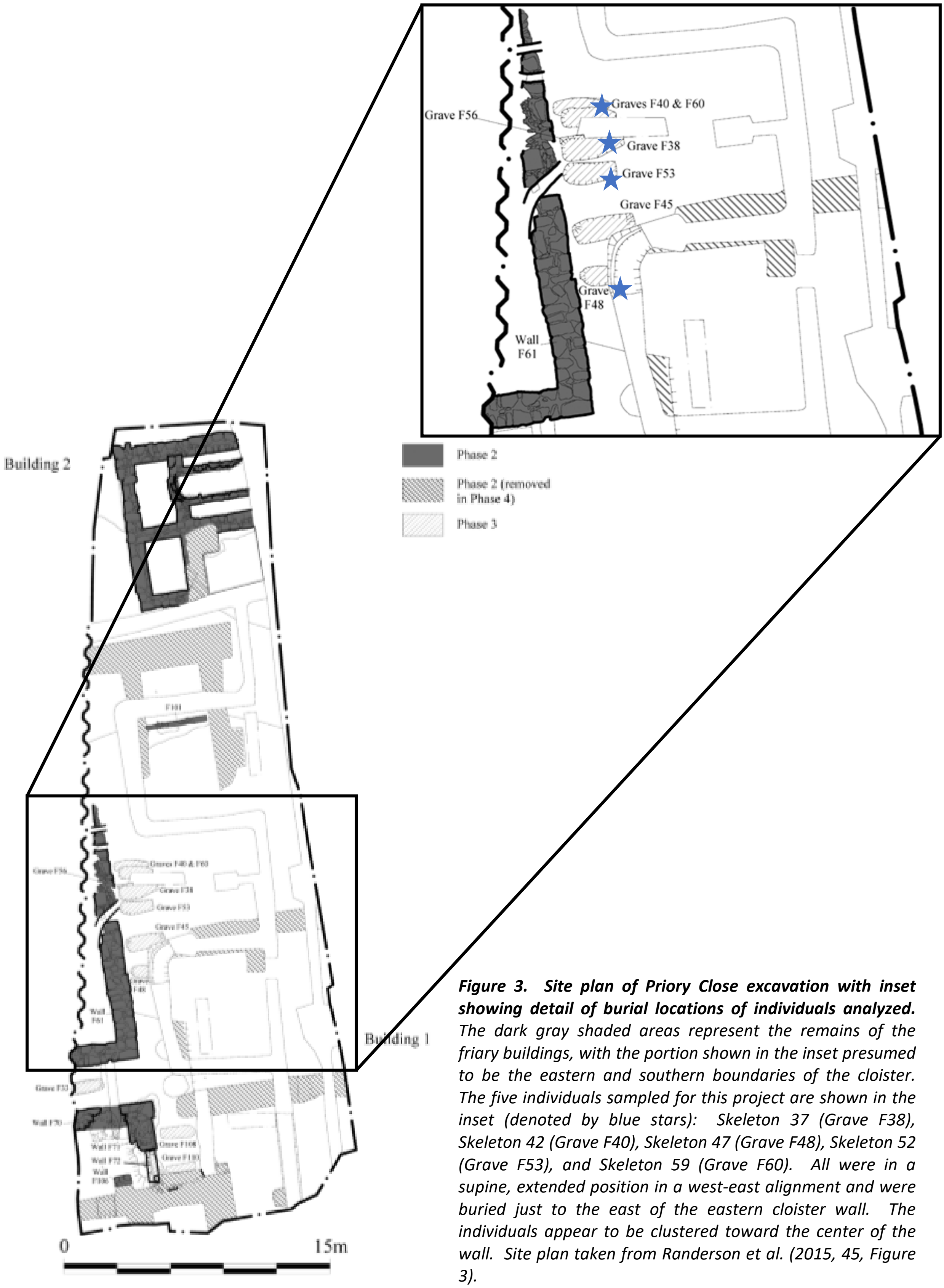

Figure 3. Site plan of Priory Close excavation with inset showing detail of burial locations of individuals analyzed. *The dark gray shaded areas represent the remains of the friary buildings, with the portion shown in the inset presumed to be the eastern and southern boundaries of the cloister. The five individuals sampled for this project are shown in the inset (denoted by blue stars): Skeleton 37 (Grave F38), Skeleton 42 (Grave F40), Skeleton 47 (Grave F48), Skeleton 52 (Grave F53), and Skeleton 59 (Grave F60). All were in a supine, extended position in a west-east alignment and were buried just to the east of the eastern cloister wall. The individuals appear to be clustered toward the center of the wall. Site plan taken from Randerson et al. (2015, 45, Figure 3).*

2.1.2 Clavering Place

Despite their short-lived existence, the Friars of the Sack nevertheless established a friary in Clavering Place, Newcastle-upon-Tyne, in AD 1266 (Emery 1960). Following the dissolution of the Order in AD 1274, the remaining Friars of the Sack occupied the location until it was taken over by the Carmelites in AD 1307 (Emery 1943), and they in turn occupied the friary until its Dissolution in AD 1539 (Claydon 2016). Fourteen skeletons dating to the medieval period were recovered when the site was excavated by Archaeological Services, Durham University, in 2008–2009 and 2014 (*ibid.*). Of these individuals, four adult males were buried in the presumed chapter house, and the other ten individuals were buried in the graveyard located southeast of the church (*ibid.*). The individuals in the graveyard included three adolescents (age 13–17 years), while the remaining adults were estimated to be male except for one whose sex was unable to be determined (Caffell and Newman 2016).

The individuals selected for isotopic analysis included two individuals from the chapter house and three from the cemetery southeast of the church (Figures 4 and 5; Claydon 2016). The chapter house was traditionally the favoured burial location for monastic superiors, although there is evidence that the chapter house in friaries of various religious orders tended to include juveniles (Gilchrist and Sloane 2005, 60, 67). In contrast to Priory Close, the individuals selected from Clavering Place were all younger adults of 18-35 years of age (Table 1). It is thus possible that the burials in the chapter house (Sks. CP-10 and CP-11) were lay individuals under the care of the friars, whereas there is evidence to suggest that the other three individuals (Sks. CP-7, CP-17, CP-19), excavated from the area southeast of the church, were the friars: although there are exceptions, there are many published plans of cemetery layouts that typically designate this area for burial of religious individuals including monks or canons (Gilchrist and Sloane 2005, 60), therefore it is plausible that this area may have had the same designation in a friary as well.

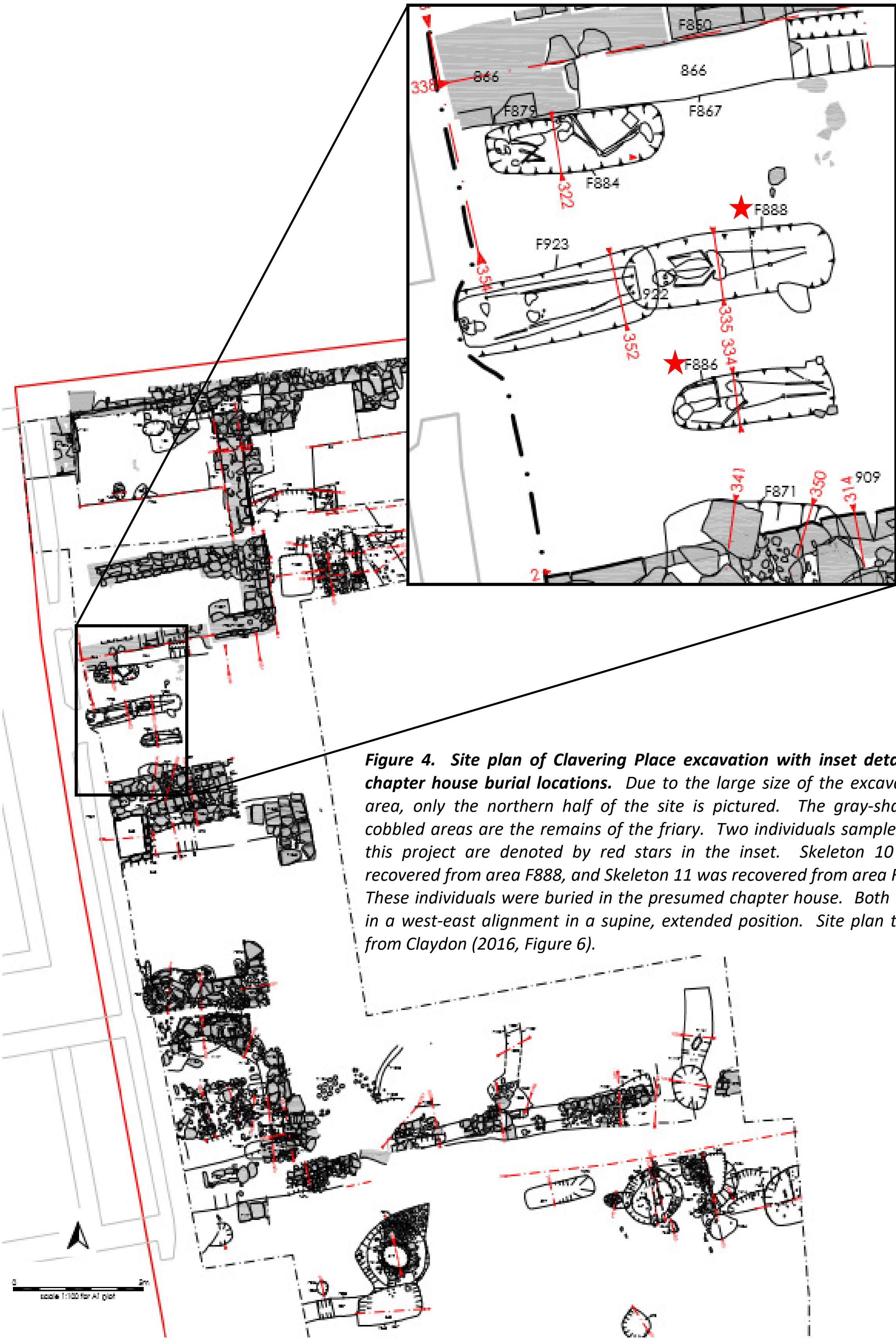

Figure 4. Site plan of Clavering Place excavation with inset detailing chapter house burial locations. *Due to the large size of the excavation area, only the northern half of the site is pictured. The gray-shaded, cobbled areas are the remains of the friary. Two individuals sampled for this project are denoted by red stars in the inset. Skeleton 10 was recovered from area F888, and Skeleton 11 was recovered from area F886. These individuals were buried in the presumed chapter house. Both were in a west-east alignment in a supine, extended position. Site plan taken from Claydon (2016, Figure 6).*

Figure 5. Site plan of Clavering Place excavation with inset detailing location of burials in cemetery southeast of the church*.* *Due to the large size of the excavation, only the northern half of the site is pictured here. The gray-shaded, cobbled areas are the remains of the friary buildings. The southern wall of the church is the northernmost wall in this plan, thus making the location of the burials detailed in the inset the southeastern cemetery. Three of the individuals analyzed in this study, denoted by red stars, were located here. Skeleton 7 was recovered from area F89, Skeleton 17 was recovered from area 1082, and Skeleton 19 was recovered from area 1252. All were in a west-east alignment in a supine, extended position. Site plan taken from Claydon (2016, Figure 6).*

Table 1. Basic data for each individual analyzed. *Data obtained from Caffell (2007) and Caffell and Newman (2016).*

Site/Skeleton	Sex	Age	Tooth	Location	Pathology
PC-37	M	36-45	LM^3	ECA	
PC-42	M	36-45	RM^3	ECA	Possible DISH
PC-47	M?	26-35?	LM_3	ECA	
PC-52	?	46+	RM_3	ECA	Possible DISH
PC-59	M?	36-45	LM_3	ECA	DISH
CP-7	M	18-25	LM_3	SEC	
CP-10	M	26-35	LM^3	CH	
CP-11	M	18-25	LM_3	CH	
CP-17*	M	25-35	LM_3	SEC	
CP-19*	M	25-35	LM_3	SEC	

Abbreviations: PC—Priory Close; CP—Clavering Place; ECA—eastern cloister alley; SEC—southeastern cemetery; CH—chapter house

*--these individuals were recovered from the more recent 2014 excavation and have not yet been reburied

LM3—left permanent 3rd molar; RM3—right permanent 3rd molar; superscript 3—maxillary; subscript 3—mandibular

2.2 Methods

Third molars (M3) and rib samples were obtained from nine adult male individuals and one adult of indeterminate sex aged 46+ years: five from Priory Close and five from Clavering Place (Table 1). Third molars have the most variable formation times of all tooth types (Zandi *et al.* 2015) but crown inception is broadly assumed not to start prior to 8.5 years of age and root apex closure occurs around the age of 23.5 years (AlQahtani *et al.* 2010). Dentine profiles from M3s thus record diet from childhood through adolescence and into early adulthood (Beaumont and Montgomery 2015) which should encompass entry into the religious order and any subsequent dietary changes: there is historical documentation of Carmelite constitutions that were approved in AD 1462 which stated that the minimum age for formally entering the religious order was to be no younger than 18 years of age (Andrews 2006, 67). Beyond the age of 23, rib bone was taken to represent adult diet in the years prior to death (Hedges et al. 2007).

For each individual, using a dental saw, a single third molar root and its corresponding crown portion was separated from the tooth, and the enamel from the crown portion was removed. Incremental dentine collagen was prepared for δ^{13}C and δ^{15}N analysis as per the protocol described in Method 2 of Beaumont *et al.* (2013). Additionally, bulk δ^{13}C and δ^{15}N isotopes were obtained from a rib fragment from each individual following the Longin method (1971). Twelve bulk long bone collagen samples from contemporaneous animals at the sites were also analyzed in order to obtain a baseline isotopic signal. The bulk bone collagen samples were measured in duplicate and mean values calculated. Dentine sections were not measured in duplicate.

The samples were measured in the Stable Isotope Biogeochemistry Laboratory (SIBL) at Durham University. Total organic carbon, total nitrogen content, and stable isotope analysis of the samples were performed using a Costech Elemental Analyser (ECS 4010) connected to a Thermo Scientific Delta V Advantage isotope ratio mass spectrometer. Carbon isotope ratios were corrected for ^{17}O contribution and reported in standard delta (δ) notation in per mil (‰) relative to Vienna Pee Dee Belemnite (VPDB). Isotopic accuracy was monitored through routine analyses of in-house standards, which were stringently calibrated against international standards (e.g., USGS

40, USGS 24, IAEA 600, IAEA N1, IAEA N2): this provided a linear range in $\delta^{13}C$ between –44‰ and 3‰ and in $\delta^{15}N$ between –7.5‰ and 20.4‰. Analytical uncertainty in carbon and nitrogen isotope analysis was typically ±0.1‰ for replicate analyses of the international standards and <0.2‰ on replicate sample analysis. Total organic carbon and nitrogen data was obtained as part of the isotopic analysis using an internal standard (Glutamic Acid, 40.82% C, 9.52% N).

The distribution of data points along the age scale in the isotopic profiles follows the methodology of Beaumont and Montgomery (2015). Because the size of each increment is equivalent (1mm), it is assumed that each increment, on average, accounts for the same length of time that the tooth was forming. Therefore, the data points for each section of tooth are evenly distributed throughout the range of years that, on average, the third molar forms. As recommended by Beaumont and Montgomery (2015), this range is taken from the London Atlas and is 8.5 to 23.5 years of age—a period of 15 years (AlQahtani *et al.* 2010). To find the length of time that each section represents, the period of formation of third molars (15 years) was divided by the number of sections obtained for each tooth. For example, tooth 1101 (from Sk. PC-37) was sectioned into a total of 16 increments. Therefore, each section represents approximately 0.94 years of formation (15 years of formation divided by 16 increments).

3 Results and Discussion

The isotopic data and collagen quality indicators for both humans and fauna can be found in Tables 2 and 3. The C:N ratios of the incremental dentine and bulk bone samples all fall within the range of 3.1 to 3.5, thus indicating that the recovered collagen is of acceptable quality (van Klinken 1999). Additionally, all the collagen yields are above 1% by weight, recommended as the minimum value indicative of sufficiently well-preserved collagen (*ibid.*). A summary of the $\delta^{13}C$ and $\delta^{15}N$ values can be found in Table 4 and the individual $\delta^{15}N$ dentine profiles for both sites are compared in Figure 6 and $\delta^{13}C$ profiles in Figure 7. The $\delta^{13}C$ bone collagen values indicative of average adult diet range from -19.4‰ to -18.5‰ and $\delta^{15}N$ from 12.8‰ to 14.3‰, i.e. small ranges that do not exceed 1.5‰. For both sites, the mean $\delta^{13}C$ value is -18.9 ± 0.3‰, while the mean $\delta^{15}N$ value for Priory Close is 13.8 ± 0.6 ‰ and for Clavering Place is 13.2 ± 0.3‰.

When the data from both sites are combined, the overall mean $\delta^{13}C$ value is -18.9 ± 0.3‰ and the overall mean $\delta^{15}N$ value is 13.5 ± 0.5‰. The dentine samples representing adolescence and early adulthood have a much greater range of -21.5‰ to -17.9‰ in the case of $\delta^{13}C$ and 9.9‰ to 15.1‰ for $\delta^{15}N$. The $\delta^{13}C$ values range from -22.3‰ to -21.0‰, and $\delta^{15}N$ from 4.0‰ to 11.0‰ in the faunal bone samples (Figure 8). There is a 3.1‰ increase in $\delta^{13}C$ and a 7.6‰ increase in $\delta^{15}N$ values between herbivore and human means. These values are higher than the expected trophic shift and provide evidence that the humans were subsisting on more than just the terrestrial herbivores. There is a 2.4‰ increase in $\delta^{13}C$ and a 3.9‰ increase in $\delta^{15}N$ values between the omnivore and human means. Although the mean omnivore $\delta^{15}N$ value potentially lies within one trophic level of the humans, the increase in $\delta^{13}C$ exceeds any expected trophic shift, which, for $\delta^{13}C$, has been shown to be less than 1‰ (Schoeninger and DeNiro 1984). It is therefore unlikely that pork consumption played a significant role in the humans' elevated $\delta^{15}N$. The archaeological evidence from the two sites supports this conclusion, as out of the total number of medieval cattle, sheep, and pig bones recovered from each site, the pig bones comprise the minority and represent no more than 10% of the total number of bones from these three species at each site (Gidney 2007, 2016). Additionally, beef was the most common meat consumed during medieval times, with pork being the second most common (Albarella 2006, 73).

The most likely reason for the high human $\delta^{13}C$ and $\delta^{15}N$ values at these sites is the consumption of marine fish. It is documented that during this time period there was an enormous demand for fish, especially marine fish, as a penitential food, and that monasteries embraced fish in substantial quantities (Serjeantson and Woolgar 2006, 102; Woolgar et al. 2006, 273). This is further substantiated when considering the $\delta^{13}C$ end points for entirely terrestrial and marine diets which have been estimated to be -21.0‰ and -12.4‰, respectively (Montgomery *et al.* 2013). The average $\delta^{13}C$ value for the sites is -18.9‰ which lies in between these two end points. Because it lies more toward the terrestrial end point, it is most likely that terrestrial protein was consumed in

Table 2. Human dentine and rib bone collagen isotope data and collagen quality indicators. *For the bulk rib bone collagen data, note that the $\delta^{13}C$ (‰), $\delta^{15}N$ (‰), %C, %N, and C:N ratios* were *obtained by averaging the duplicate runs.*

Individual	Lab Code	Type	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N	Collagen Yield (%)
PC-37	1101-1	Dentine	-19.9	11.8	41.4	14.9	3.2	
PC-37	1101-2	Dentine	-20.3	11.2	41.4	15.0	3.2	
PC-37	1101-3	Dentine	-20.6	11.0	40.7	14.9	3.2	
PC-37	1101-4	Dentine	-20.2	11.4	41.4	15.2	3.2	
PC-37	1101-5	Dentine	-20.0	12.1	41.1	15.1	3.2	
PC-37	1101-6	Dentine	-19.8	12.4	41.4	15.2	3.2	
PC-37	1101-7	Dentine	-19.5	12.2	42.0	15.1	3.2	
PC-37	1101-8	Dentine	-19.6	12.3	41.9	15.2	3.2	15.9
PC-37	1101-9	Dentine	-19.6	12.2	41.7	15.1	3.2	
PC-37	1101-10	Dentine	-19.6	12.1	41.5	15.1	3.2	
PC-37	1101-11	Dentine	-19.5	12.0	41.9	15.1	3.2	
PC-37	1101-12	Dentine	-19.7	12.0	41.8	15.1	3.2	
PC-37	1101-13	Dentine	-19.4	12.3	42.4	15.2	3.3	
PC-37	1101-14	Dentine	-19.4	12.5	41.8	15.1	3.2	
PC-37	1101-15	Dentine	-19.6	12.9	42.0	15.1	3.2	
PC-37	1101-16	Dentine	-19.6	13.1	42.5	14.9	3.3	
PC-37	1111	Rib Bone	-19.4	12.9	42.7	15.5	3.2	18.1
PC-42	1102-1	Dentine	-19.4	13.2	42.4	15.4	3.2	
PC-42	1102-2	Dentine	-19.4	12.4	36.2	12.9	3.3	
PC-42	1102-3	Dentine	-19.2	12.3	43.1	15.4	3.3	
PC-42	1102-4	Dentine	-19.3	12.4	42.0	15.3	3.2	
PC-42	1102-5	Dentine	-19.2	12.6	42.4	15.2	3.3	
PC-42	1102-6	Dentine	-19.2	13.2	42.1	15.2	3.2	
PC-42	1102-7	Dentine	-19.3	13.7	42.3	15.2	3.2	
PC-42	1102-8	Dentine	-18.9	13.6	42.9	15.2	3.3	18.2
PC-42	1102-9	Dentine	-18.8	13.6	42.7	15.3	3.3	
PC-42	1102-10	Dentine	-18.7	13.7	41.7	15.2	3.2	
PC-42	1102-11	Dentine	-18.8	13.8	42.5	15.1	3.3	
PC-42	1102-12	Dentine	-18.7	14.0	42.5	15.2	3.3	
PC-42	1102-13	Dentine	-18.8	13.9	41.8	15.1	3.2	
PC-42	1102-14	Dentine	-19.2	13.8	42.6	15.0	3.3	
PC-42	1102-15	Dentine	-19.0	14.4	43.2	15.2	3.3	
PC-42	1112	Rib Bone	-19.0	14.0	43.0	15.7	3.2	24.1
PC-47	1103-1	Dentine	-19.3	12.8	42.7	15.3	3.2	
PC-47	1103-2	Dentine	-19.0	12.9	43.1	15.4	3.3	
PC-47	1103-3	Dentine	-19.0	12.4	43.2	15.4	3.3	
PC-47	1103-4	Dentine	-18.6	12.7	42.8	15.3	3.3	
PC-47	1103-5	Dentine	-18.8	13.2	42.3	15.1	3.3	
PC-47	1103-6	Dentine	-19.0	13.2	43.6	15.4	3.3	17.1
PC-47	1103-7	Dentine	-18.8	13.4	42.8	15.2	3.3	
PC-47	1103-8	Dentine	-18.8	13.4	42.4	15.4	3.2	
PC-47	1103-9	Dentine	-18.6	13.6	42.5	15.4	3.2	
PC-47	1103-10	Dentine	-18.5	13.7	43.5	15.4	3.3	
PC-47	1103-11	Dentine	-18.8	13.5	41.9	15.3	3.2	
PC-47	1103-12	Dentine	-19.1	13.9	42.9	15.3	3.3	
PC-47	1113	Rib Bone	-19.0	13.4	42.8	15.5	3.2	20.0

(continued)

Individual	Lab Code	Type	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N	Collagen Yield (%)
PC-52	1104-1	Dentine	-18.7	14.2	43.5	15.3	3.3	
PC-52	1104-2	Dentine	-18.4	13.8	42.8	15.4	3.2	
PC-52	1104-3	Dentine	-18.7	13.7	42.2	15.5	3.2	
PC-52	1104-4	Dentine	-18.8	13.7	42.6	15.3	3.2	
PC-52	1104-5	Dentine	-18.7	13.4	42.3	15.3	3.2	
PC-52	1104-6	Dentine	-18.4	13.8	42.7	15.4	3.2	
PC-52	1104-7	Dentine	-18.2	14.2	42.1	15.2	3.2	
PC-52	1104-8	Dentine	-17.9	14.4	41.4	15.2	3.2	18.0
PC-52	1104-9	Dentine	-18.0	14.8	43.1	15.3	3.3	
PC-52	1104-10	Dentine	-17.9	15.1	42.7	15.2	3.3	
PC-52	1104-11	Dentine	-18.1	14.9	40.1	14.4	3.2	
PC-52	1104-12	Dentine	-18.2	14.9	42.9	15.2	3.3	
PC-52	1104-13	Dentine	-18.0	14.9	42.8	15.1	3.3	
PC-52	1104-14	Dentine	-18.0	15.1	42.5	15.3	3.3	
PC-52	1104-15	Dentine	-18.1	15.0	42.6	15.1	3.3	
PC-52	1114	Rib Bone	-18.5	14.3	43.4	15.7	3.2	18.8
PC-59	1105-1	Dentine	-19.0	14.1	41.8	15.4	3.2	
PC-59	1105-2	Dentine	-18.9	14.1	42.1	15.6	3.1	
PC-59	1105-3	Dentine	-19.0	14.3	41.9	15.5	3.2	
PC-59	1105-4	Dentine	-19.0	14.2	42.0	15.5	3.2	
PC-59	1105-5	Dentine	-18.9	14.0	42.0	15.3	3.2	
PC-59	1105-6	Dentine	-18.7	14.0	41.8	15.4	3.2	
PC-59	1105-7	Dentine	-18.9	13.8	40.9	15.3	3.1	
PC-59	1105-8	Dentine	-18.8	13.9	42.2	15.4	3.2	16.6
PC-59	1105-9	Dentine	-19.0	13.9	41.0	15.5	3.1	
PC-59	1105-10	Dentine	-19.0	14.2	42.1	15.3	3.2	
PC-59	1105-11	Dentine	-18.8	14.6	42.2	15.3	3.2	
PC-59	1105-12	Dentine	-18.9	14.8	41.7	15.3	3.2	
PC-59	1105-13	Dentine	-18.7	14.5	41.6	15.3	3.2	
PC-59	1105-14	Dentine	-18.9	14.6	42.0	15.3	3.2	
PC-59	1105-15	Dentine	-18.5	15.0	41.8	15.4	3.2	
PC-59	1105-16	Dentine	-18.7	14.7	42.0	15.3	3.2	
PC-59	1115	Rib Bone	-18.7	14.2	43.9	15.8	3.2	24.6
CP-7	1106-1	Dentine	-20.2	12.0	41.0	15.3	3.1	
CP-7	1106-2	Dentine	-19.9	11.6	42.0	15.4	3.2	
CP-7	1106-3	Dentine	-19.8	11.6	41.5	15.5	3.1	
CP-7	1106-4	Dentine	-19.6	12.0	41.3	15.2	3.2	
CP-7	1106-5	Dentine	-19.7	11.7	41.8	15.5	3.1	
CP-7	1106-6	Dentine	-19.7	11.3	41.4	15.4	3.1	
CP-7	1106-7	Dentine	-19.5	11.7	41.6	15.3	3.2	
CP-7	1106-8	Dentine	-19.3	11.7	41.6	15.3	3.2	
CP-7	1106-9	Dentine	-18.7	13.1	41.6	15.2	3.2	14.2
CP-7	1106-10	Dentine	-18.5	13.4	41.7	15.4	3.2	
CP-7	1106-11	Dentine	-18.5	13.3	41.4	15.2	3.2	
CP-7	1106-12	Dentine	-18.5	13.2	41.6	15.2	3.2	
CP-7	1106-13	Dentine	-18.4	13.7	41.3	15.3	3.2	
CP-7	1106-14	Dentine	-18.2	14.0	41.8	15.2	3.2	
CP-7	1106-15	Dentine	-18.0	14.7	42.0	15.2	3.2	
CP-7	1106-16	Dentine	-18.1	14.6	40.5	14.9	3.2	
CP-7	1116	Rib Bone	-18.5	13.5	43.1	15.7	3.2	19.4
								(continued)

Individual	Lab Code	Type	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N	Collagen Yield (%)
CP-10	1107-1	Dentine	-19.6	13.1	41.9	15.2	3.2	
CP-10	1107-2	Dentine	-19.3	12.9	42.5	15.5	3.2	
CP-10	1107-3	Dentine	-19.2	12.8	42.4	15.5	3.2	
CP-10	1107-4	Dentine	-19.1	13.3	42.6	15.5	3.2	
CP-10	1107-5	Dentine	-19.3	13.4	42.9	15.5	3.2	
CP-10	1107-6	Dentine	-19.4	13.6	42.8	15.6	3.2	
CP-10	1107-7	Dentine	-19.0	13.9	42.0	15.4	3.2	
CP-10	1107-8a	Dentine	-18.9	14.1	42.3	15.2	3.2	
CP-10	1107-9a	Dentine	-18.5	14.2	42.3	15.3	3.2	18.1
CP-10	1107-10a	Dentine	-18.5	14.4	42.8	15.4	3.2	
CP-10	1107-11a	Dentine	-18.7	14.6	42.8	15.5	3.2	
CP-10	1107-12a	Dentine	-18.8	15.1	43.8	15.4	3.3	
CP-10	1107-13a	Dentine	-18.8	14.3	43.8	15.4	3.3	
CP-10	1107-14a	Dentine	-18.6	14.3	43.7	15.4	3.3	
CP-10	1107-15a	Dentine	-18.7	14.7	42.8	15.4	3.2	
CP-10	1107-16a	Dentine	-18.9	14.7	43.1	15.4	3.3	
CP-10	1107-17a	Dentine	-18.9	14.8	43.3	15.4	3.3	
CP-10	1117	Rib Bone	-19.0	13.7	43.6	15.6	3.3	16.6
CP-11	1108-1	Dentine	-19.8	12.3	42.2	15.3	3.2	
CP-11	1108-2	Dentine	-19.8	12.3	43.1	15.6	3.2	
CP-11	1108-3	Dentine	-19.3	12.8	43.0	15.5	3.2	
CP-11	1108-4	Dentine	-18.8	12.9	42.2	15.3	3.2	
CP-11	1108-5	Dentine	-18.8	12.9	41.6	15.2	3.2	
CP-11	1108-6	Dentine	-18.6	12.7	42.9	15.3	3.3	16.5
CP-11	1108-7	Dentine	-18.8	12.9	43.1	15.3	3.3	
CP-11	1108-8	Dentine	-19.1	13.3	43.2	15.4	3.3	
CP-11	1108-9	Dentine	-18.6	13.7	42.6	15.4	3.2	
CP-11	1108-10	Dentine	-18.6	14.1	42.7	15.3	3.2	
CP-11	1108-11	Dentine	-18.6	13.9	42.3	15.3	3.2	
CP-11	1108-12	Dentine	-18.6	13.9	42.9	15.2	3.3	
CP-11	1118	Rib Bone	-18.8	13.0	43.3	15.9	3.2	22.0
CP-17	1109-1	Dentine	-20.0	13.2	41.4	15.3	3.2	
CP-17	1109-2	Dentine	-19.8	12.6	41.6	15.6	3.1	
CP-17	1109-3	Dentine	-19.6	11.9	42.3	15.6	3.2	
CP-17	1109-4	Dentine	-18.8	12.6	41.1	15.6	3.1	
CP-17	1109-5	Dentine	-19.1	12.3	42.4	15.6	3.2	
CP-17	1109-6	Dentine	-19.0	12.5	42.2	15.6	3.2	
CP-17	1109-7	Dentine	-19.1	12.9	41.8	15.6	3.1	14.5
CP-17	1109-8	Dentine	-18.7	13.1	42.1	15.5	3.2	
CP-17	1109-9	Dentine	-18.8	12.9	41.0	15.4	3.1	
CP-17	1109-10	Dentine	-18.7	13.2	41.9	15.5	3.2	
CP-17	1109-11	Dentine	-18.8	13.6	41.4	15.4	3.1	
CP-17	1109-12	Dentine	-18.7	14.1	42.4	15.4	3.2	
CP-17	1109-13	Dentine	-18.6	14.2	42.0	15.2	3.2	
CP-17	1119	Rib Bone	-19.0	13.2	43.4	15.2	3.3	8.0
								(continued)

Individual	Lab Code	Type	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N	Collagen Yield (%)
CP-19	1110-1	Dentine	-21.4	10.8	43.2	15.4	3.3	15.0
CP-19	1110-2	Dentine	-21.5	9.9	42.5	15.3	3.2	
CP-19	1110-3	Dentine	-20.6	9.9	44.0	15.5	3.3	
CP-19	1110-4	Dentine	-20.8	10.6	41.5	15.3	3.2	
CP-19	1110-5	Dentine	-20.2	10.2	42.3	15.4	3.2	
CP-19	1110-6	Dentine	-20.2	9.9	41.6	14.9	3.3	
CP-19	1110-7	Dentine	-19.9	10.6	43.7	15.4	3.3	
CP-19	1110-8	Dentine	-20.0	10.9	42.9	15.3	3.3	
CP-19	1110-9	Dentine	-19.5	11.5	43.4	15.4	3.3	
CP-19	1110-10	Dentine	-19.4	12.6	42.6	15.3	3.2	
CP-19	1110-11	Dentine	-19.8	12.5	43.1	15.2	3.3	
CP-19	1110-12	Dentine	-19.8	12.9	43.1	15.2	3.3	
CP-19	1120	Rib Bone	-19.3	12.8	42.8	15.7	3.2	22.4

Abbreviations: PC - Priory Close; CP - Clavering Place

Site/Context*	Lab Code	Species	Type	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N	Collagen Yield (%)
NCP08 50	1221	cow	MC	-22.3	5.0	41.9	14.4	3.4	2.4
NCP08 50	1222	pig	mandible	-21.0	11.0	32.9	11.8	3.2	7.8
NCP08 50	1223	sheep	radius	-21.8	9.3	41.7	15.1	3.2	9.5
NCP08 297	1224	cow	1st phalanx	-22.2	6.1	43.2	15.5	3.2	14.2
NCP08 519	1225	pig	humerus	-21.3	9.5	43.5	15.5	3.3	15.8
NCP08 519	1226	sheep	mandible	-22.3	5.2	44.7	15.8	3.3	18.3
NCP08 519	1227	cow	mandible	-22.1	5.0	44.3	16.2	3.2	20.2
NCP08 590	1228	cow	MC	-21.9	6.7	42.6	15.6	3.2	12.8
NCP08 590	1229	sheep	mandible	-22.1	5.6	41.7	15.0	3.2	8.7
NCP14 117	1230	pig	MC3	-21.6	8.4	41.3	15.2	3.2	8.1
NPC06 26	1231	cow	MT	-22.0	5.8	42.5	15.7	3.2	13.5
NPC06 43	1232	cow	humerus	-21.7	4.0	41.9	14.9	3.3	2.9

*NCP08 and NCP14-Clavering Place, Newcastle; NPC06-Priory Close, Northallerton

Abbreviations: MC - metacarpal; MT - metatarsal

Table 3. Faunal isotope data and collagen quality indicators. *Note that the $\delta^{13}C$ (‰), $\delta^{15}N$ (‰), %C, %N, and C:N ratios were obtained by averaging the duplicate runs.*

		First Dentine Section		Last Dentine Section		Minimum		Maximum		Dentine Mean		Rib Collagen	
Individual	**Lab Code**	**δ^{13}C (‰)**	**δ^{15}N (‰)**	**δ^{13}C (‰)**	**δ^{15}N (‰)**	**δ^{13}C (‰)**	**δ^{15}N (‰)**	**δ^{13}C (‰)**	**δ^{15}N (‰)**	**δ^{13}C (‰)**	**δ^{15}N (‰)**	**δ^{13}C (‰)**	**δ^{15}N (‰)**
PC-37	1101	-19.9	11.8	-19.6	13.1	-20.6	11.0	-19.4	13.1	-19.8 ± 0.3	12.1 ± 0.6	-19.4	12.9
PC-42	1102	-19.4	13.2	-19.0	14.4	-19.4	12.3	-18.7	14.4	-19.1 ± 0.3	13.4 ± 0.7	-19.0	14.0
PC-47	1103	-19.3	12.8	-19.1	13.9	-19.3	12.4	-18.5	13.9	-18.9 ± 0.2	13.2 ± 0.4	-19.0	13.4
PC-52	1104	-18.7	14.2	-18.1	15.0	-18.8	13.4	-17.9	15.1	-18.3 ± 0.3	14.4 ± 0.6	-18.5	14.3
PC-59	1105	-19.0	14.1	-18.7	14.7	-19.1	13.8	-18.5	15.0	-18.9 ± 0.2	14.3 ± 0.4	-18.7	14.2
CP-7	1106	-20.2	12.0	-18.1	14.6	-20.2	11.3	-18.0	14.7	-19.0 ± 0.8	12.7 ± 1.2	-18.5	13.5
CP-10	1107	-19.6	13.2	-18.9	14.8	-19.6	12.8	-18.5	15.1	-19.0 ± 0.3	14.0 ± 0.7	-19.0	13.7
CP-11	1108	-19.8	12.3	-18.6	13.9	-19.8	12.3	-18.6	14.1	-18.9 ± 0.5	13.2 ± 0.6	-18.8	13.0
CP-17	1109	-20.0	13.2	-18.6	14.2	-20.0	11.9	-18.6	14.2	-19.1 ± 0.5	13.0 ± 0.7	-19.0	13.2
CP-19	1110	-21.4	10.8	-19.8	12.9	-21.5	9.9	-19.4	12.9	-20.3 ± 0.7	11.0 ± 1.1	-19.3	12.8

Abbreviations: PC - Priory Close; CP - Clavering Place

Table 4. Summary table of δ^{13}C and δ^{15}N values of dentine collagen sections and bulk rib collagen for all human individuals. *Means are shown ± 1 standard deviation.*

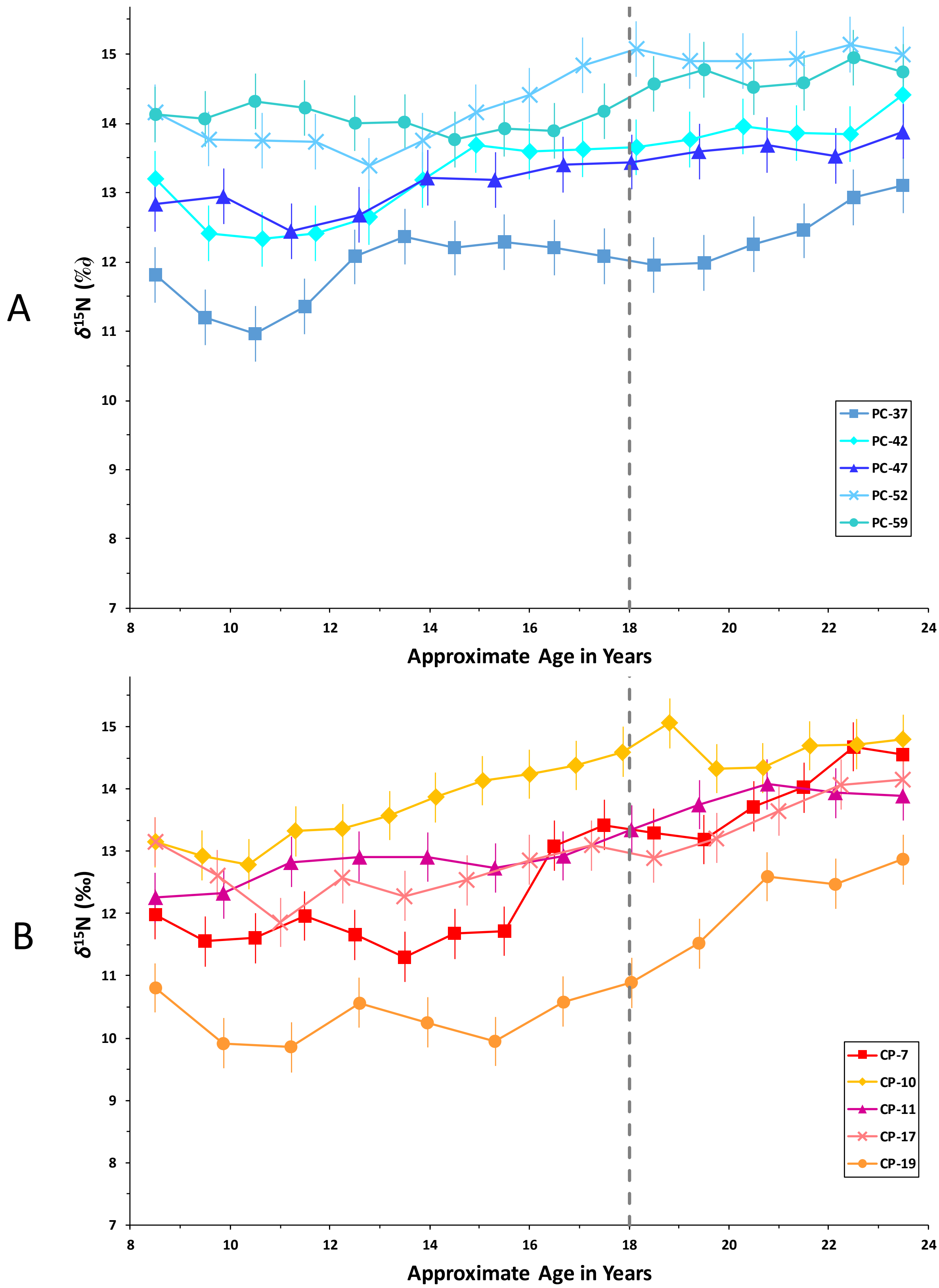

Figure 6. Dentine collagen δ^{15}N profiles of all individuals. *Plot A shows the Priory Close individuals, and plot B shows the Clavering Place individuals. The vertical dashed line shows the assumed age for entering a friary. Error bars are shown ± 0.4‰ (2 standard deviations).*

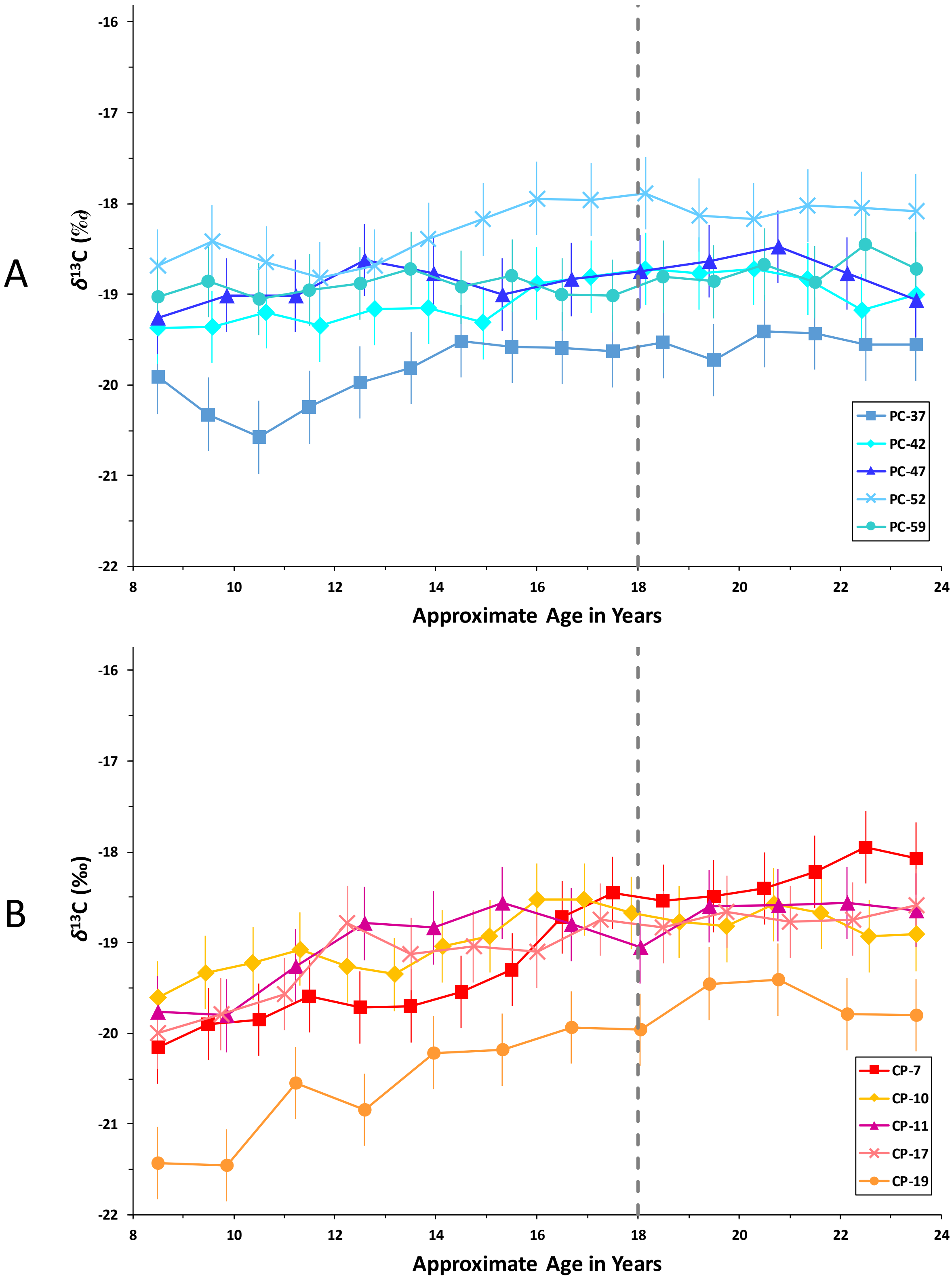

Figure 7. Dentine collagen δ^{13}C profiles of all individuals. *Plot A shows the Priory Close individuals, and plot B shows the Clavering Place individuals. The vertical dashed line shows the assumed age of entry into a friary. Error bars are shown ± 0.4‰ (2 standard deviations).*

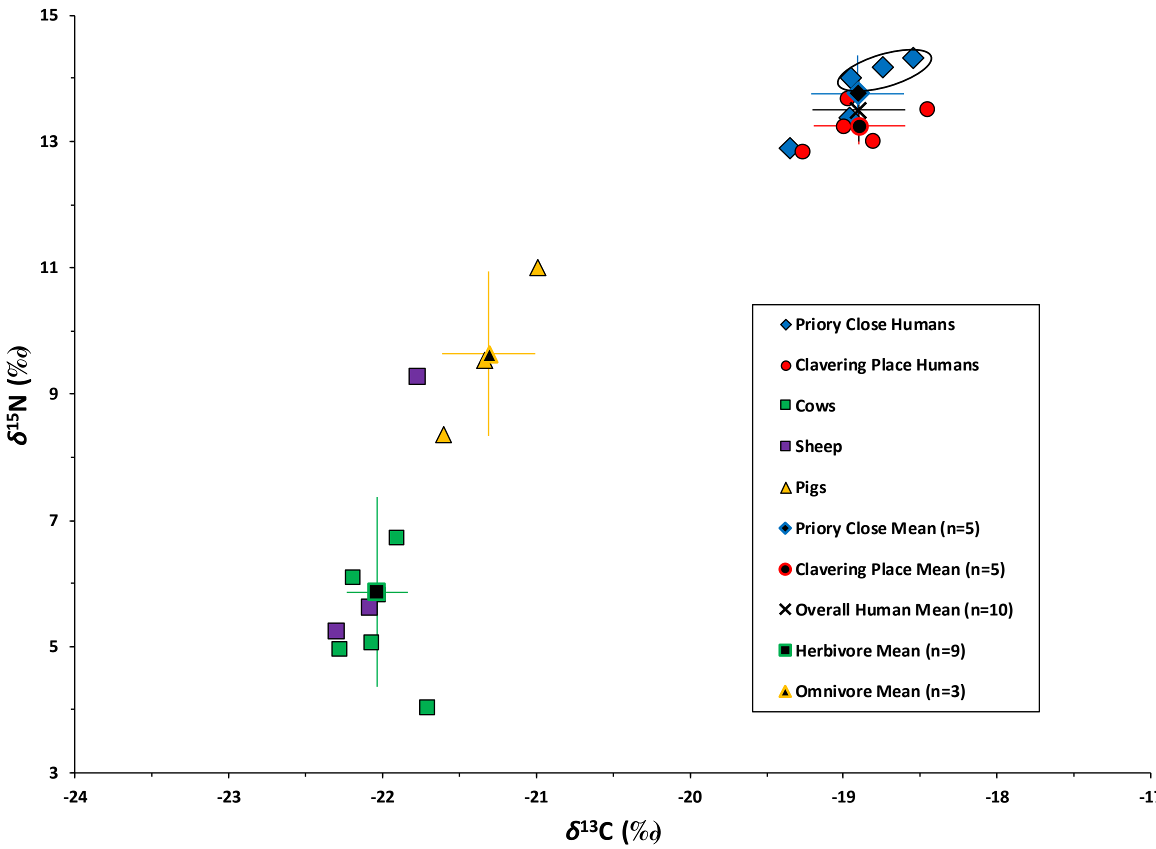

Figure 8. Individual and mean $\delta^{13}C$ and $\delta^{15}N$ values of individuals analyzed in this study. *The individuals associated with DISH are circled. Means are shown with error bars of ±1 standard deviation.*

a significant amount as well. There is archaeological evidence for this consumption, as the assemblage of animal bones from Priory Close suggests that the friars were well-fed with a staple diet of beef, veal, and mutton, with fish and shellfish available for meatless days (Randerson *et al.* 2015). This mean δ^{13}C value, being nearer to the terrestrial endpoint, may also indicate consumption of freshwater fish. Multiple studies have demonstrated that δ^{13}C values of fish are positively correlated with salinity (Fuller *et al.* 2012; Grupe *et al.* 2009; Robson *et al.* 2016), while the δ^{15}N values remain elevated, reflecting the high number of trophic levels in aquatic systems, although this can vary (Dufour 1999). That is, freshwater fish tend to have lower δ^{13}C values that overlap the terrestrial diet range, while marine fish tend to have less negative δ^{13}C values which plot beyond the expected terrestrial range. Despite evidence of a concurrent decrease in the proportion of freshwater fish as the marine fishing industry rapidly grew after AD 1000 (Barrett *et al.* 2004), the isotopic pattern seen here indicates that consumption of freshwater fish cannot be ruled out.

One of the sheep sampled from Clavering Place, Newcastle, had an unusually high δ^{15}N value of 9.3‰, about 4‰ higher than the other two sheep samples (Figure 8). One potential reason for this high value is the application of manure to crops, which elevates δ^{15}N levels (Bogaard *et al.* 2013; Fraser *et al.* 2011; Treasure *et al.* 2016; Gron *et al.* 2017) and is known to have been one of the most important means of maintaining or increasing soil productivity during the medieval period (Dyer 1997, 297). This sheep may have eaten hay from manured crops. Another possibility, considering Newcastle's proximity to the sea, was that this animal was grazed near the coast or on salt marshes, practices which also result in elevated δ^{15}N levels in domestic herbivores (Britton *et al.* 2008; Richards *et al.* 2006).

3.1 Evidence for a Change in Diet

All individual profiles showed an increase in both δ^{13}C and δ^{15}N values from crown to root (Figures 6 and 7; Table 5). These increases exceed analytical error and can therefore be considered meaningful shifts in diet. Given that the two ratios rise together, in this period such increases are most likely due to a shift from a largely terrestrial protein diet during early childhood to one containing more marine protein by early adulthood (Müldner and Richards 2007a). Although there is no consistent age at which these changes in diet appear to occur for all individuals, it seems that diet is beginning to shift, i.e. the isotopic profiles begin to increase, prior to the assumed age of entry into the religious orders (marked by the vertical dashed lines on Figures 6 and 7). Assuming these individuals are friars, this indicates that they were assuming a 'friar diet' prior to the age of 18. In the case of Priory Close, this may be due to the fact that not only was it established prior to the Carmelite constitution that stated that no one under the age of 18 was to be accepted, but documentation also attests that the Carmelites were accused of accepting boys too young (Andrews 2006, 47). According to the evidence shown by these isotopic profiles, it appears that the Friars of the Sack accepted younger boys as well. It should be stated that these observations are made cautiously because, of all the teeth, third molars have the greatest variation in age at formation and eruption (Mincer *et al.* 1993). Therefore, although it appears that the dietary shifts are occurring at different ages in each individual, it is likely that variability in age at formation of the third molar is also playing a role in the inconsistencies. Additionally, the vertical lines in Figures 6 and 7 demarcating the chronological age of 18 are provided only as a general approximation of this age, as the inherent variability makes it impossible to pinpoint chronological age with certainty.

The individuals from Clavering Place show a greater increase in $\delta^{13}C$ and $\delta^{15}N$ (1.4 ± 0.5‰ and 1.8 ± 0.6‰) than the individuals from Priory Close (0.4 ± 0.2‰ and 1.0 ± 0.3‰), suggesting they experienced a more radical change in diet (Figures 6 and 7; Table 5). This may be due to the earlier establishment of the friary at Clavering Place. Skeletons from Clavering Place have been radiocarbon dated to the 13th century AD (Claydon 2016), i.e. prior to the increase in meat consumption by the peasantry in England during the 14th and 15th centuries AD (Dyer 1989, 158-159). It is thus possible that, prior to entry into the friary, these individuals consumed a diet higher in plant protein than the individuals from Priory Close, a friary that was first established in the mid-14th century AD. The increased consumption of meat in this later period may result in higher human $\delta^{13}C$ and $\delta^{15}N$ values even before the introduction of dietary marine protein observed in the M3 teeth. This increased baseline meat consumption may also explain the slightly higher mean bone collagen $\delta^{15}N$ value (indicative of adult diet) of the Priory Close individuals (13.8 ± 0.6‰) when compared to the Clavering Place individuals (13.2 ± 0.3‰).

			Individual Differences		Average Differences per Site		Overall Average	
Site	**Individual**	**Lab Code**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**
Priory Close	PC-37	1101	0.3	1.3	0.4 ±0.2	1.0 ±0.3	0.9 ± 0.7	1.4 ± 0.6
	PC-42	1102	0.4	1.2				
	PC-47	1103	0.2	1.1				
	PC-52	1104	0.6	0.8				
	PC-59	1105	0.3	0.6				
Clavering Place	CP-7	1106	2.1	2.6	1.4 ± 0.5	1.8 ± 0.6		
	CP-10	1107	0.7	1.6				
	CP-11	1108	1.2	1.6				
	CP-17	1109	1.4	1.0				
	CP-19	1110	1.6	2.1				

Table 5. Individual isotopic differences between first and last incremental sections of dentine collagen, isotopic differences per site, and overall isotopic differences. *Averages are shown ± 1 standard deviation.*

3.2 Intra-Individual Patterns

Four out of the five individuals from Priory Close (Sks. PC-37, PC-42, PC-47, and PC-52) show a dip or decrease in their δ^{15}N profile toward the beginning of the formation of the third molar, after which the profile increases and plateaus, and in the cases of Sks. PC-37, PC-42, and PC-47 the profile increases at its end (Figure 9). With the exception of Sk. PC-52, whose δ^{15}N profile more steadily decreases rather than dips, the magnitude of these decreases in δ^{15}N are all above 2 standard deviations of analytical error and may therefore be considered meaningful changes in the profiles. For Sk. PC-37 the lowest point in δ^{15}N occurs at approximately 10.5 years of age, for PC-42 and PC-47 at approximately 11 years, and for PC-52 at approximately 13 years. During this initial decrease in δ^{15}N, the δ^{13}C profile of Sk. PC-37 is the only one to show a clear corresponding decrease that is expected to accompany a shift in diet. The others either increase (Sks. PC-42 and PC-52) or do not change (Sk. PC-47) as the δ^{15}N decreases, potentially indicating nutritional or physiological stress rather than a shift in diet (Beaumont and Montgomery 2016). This pattern of opposing co-variance (i.e. decreasing δ^{15}N and simultaneous increase in δ^{13}C or vice versa) would indicate the resolution of a period of physiological stress since the carbon and nitrogen are moving back toward one another. Additionally, only Sk. PC-42 shows a corresponding increase in δ^{13}C as the δ^{15}N increases at the end of the profile. The δ^{13}C profiles for Sks. PC-37 and PC-47 decrease as the δ^{15}N increases at this point, again showing the pattern of opposing co-variance indicative of nutritional or physiological stress (*ibid.*). This pattern at the end of the profile (i.e. increasing δ^{15}N and decreasing δ^{13}C) indicates the start of a period of physiological stress since the δ^{15}N and δ^{13}C are moving away from one another. The fifth individual from Priory Close, Sk. PC-59, does not show any radical shifts in either isotopic profile, but rather shows a slight and steady increase in both profiles.

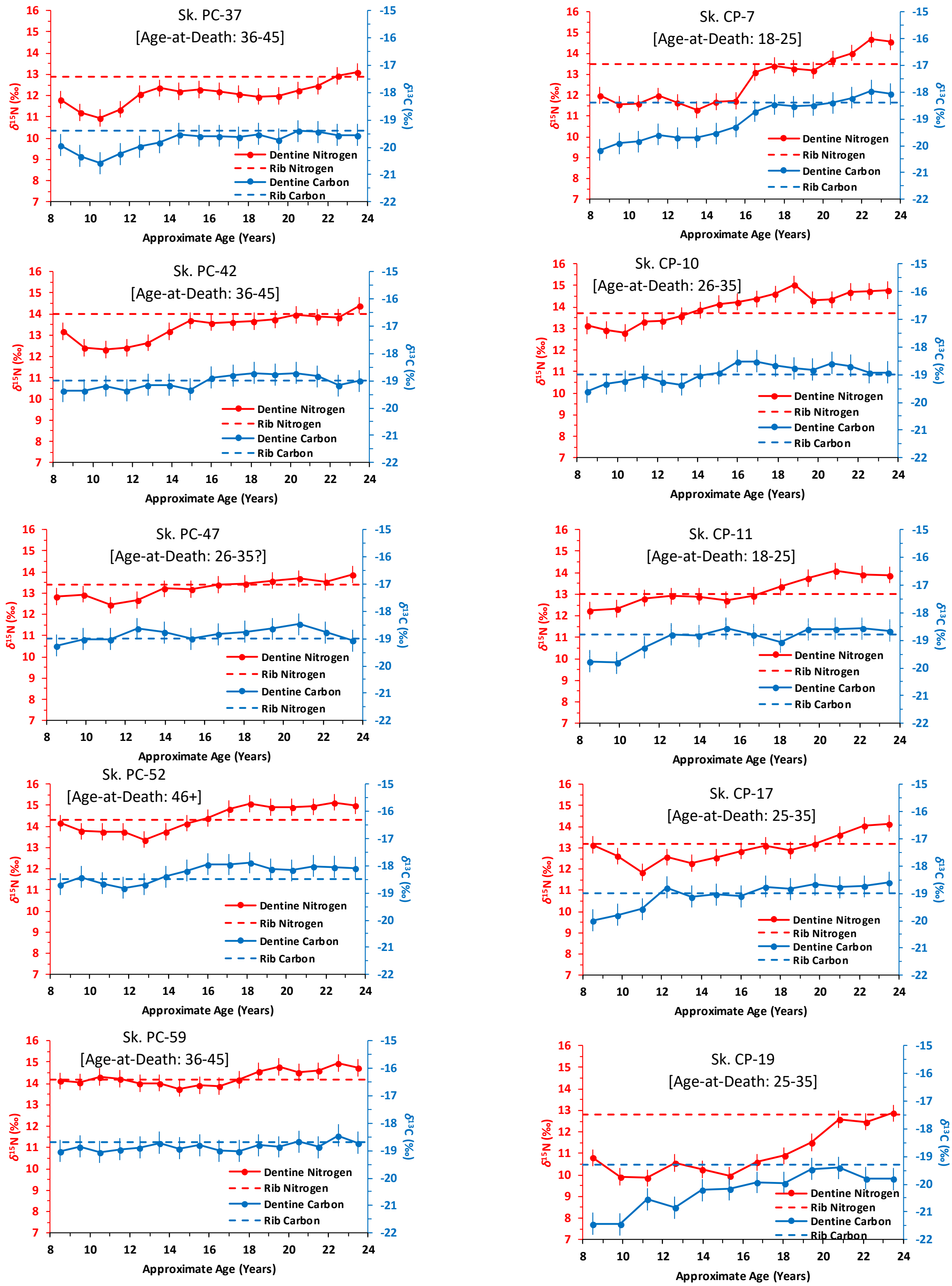

Figure 9. Dentine collagen δ^{13}C and δ^{15}N profiles and bulk rib bone δ^{13}C and δ^{15}N values for all individuals in this study. *The plots on the left half of the page are from Priory Close, and those on the right side are from Clavering Place. Error bars show ± 0.4‰ (2sd).*

Four out of the five individuals from Clavering Place (Sks. CP-7, CP-10, CP-17, and CP-19) show the pattern of opposing co-variance at the beginning of their isotopic profiles (Figure 9). Skeletons CP-10 and CP-19 show the opposing co-variance pattern at the end of their profiles as well. The isotopic profiles of Sks. CP-7 and CP-11 each show two 'plateau periods'. For Sk. CP-7, the first plateau occurs between approximately 17 and 20 years, and after an increase in each profile, the second plateau appears to occur from 22.5 years of age. For Sk. CP-11, the first plateau occurs between the ages of approximately 12 and 17 years, and after the subsequent increase, the second plateau occurs from the age of approximately 21 years. These patterns of an increase in $\delta^{13}C$ and $\delta^{15}N$ profiles to a plateau for a period of years and subsequent increase leading to another plateau indicate multiple shifts in diet.

Assuming that diet would become richer in protein as the friars moved up in rank, these additional shifts in diet may indicate further promotion within the order, although this is unlikely given the young age at which these shifts occur. A more likely possibility for multiple shifts in diet could be geographical relocation. Although friaries tended to attract those individuals from the local city or its hinterland, once recruited, the friars belonged to the order rather than to a particular friary and might move frequently to study or to fulfill their missions (Geltner 2010; Andrews 2006, 37). A move to a different geographical location may very well result in a significant shift in diet if the new location had access to different food resources.

Eight of the ten individuals analyzed for this study show either a pattern of opposing co-variance or co-variance at the beginning of the isotopic profiles resulting in a decrease in $\delta^{15}N$ during the beginning stages of the formation of the third molar. It may be possible that the individuals showing opposing co-variance, and therefore a period of physiological or nutritional stress, sought out the care of the friars during this period of illness and subsequently stayed on to join the religious order, although it is admittedly unlikely that such a high proportion of individuals analyzed in this small study would have similar circumstances in joining the friaries. These decreases in $\delta^{15}N$ may rather result from a common physiological factor occurring in males during this time-period, perhaps puberty. Although no statistically significant $\delta^{15}N$ growth effect has been noted in adolescents (Waters-Rist and Katzenberg 2010), it would nevertheless be beneficial to further investigate the potential growth effects in dentine collagen seen in this study since this tissue does not remodel once formed, thereby eliminating remodelling as a confounding variable.

Three individuals (Sks. PC-47, CP-10, and CP-19) have an estimated age at death range (25/26 to 35 years of age) that begins soon after the third molar stops forming (approximately 23 years of age). These three individuals also show the pattern of opposing co-variance at the end of their isotopic profiles (Figure 9). Because of the proximity of the start of these periods of physiological stress to the estimated age-at-death ranges, it is possible that these patterns of opposing co-variance indicate the start of illness or conditions that contributed to these individuals' deaths.

Overall there is a trend for the rib bone collagen δ^{13}C and δ^{15}N values to plot below the values of the final sections of the dentine collagen δ^{13}C and δ^{15}N values (Figure 9; Table 6). When averaging this data per site, however, the only mean greater than standard error (i.e. 0.4‰, 2sd) is that of the -0.7‰ δ^{15}N difference of the Clavering Place individuals. The most likely reason for these larger differences is the younger age of the individuals at Clavering Place. Because bone collagen contains a long-term average of the δ^{13}C and δ^{15}N values of the diet (Hedges *et al.* 2007), it takes years for it to reflect the isotopic signals of a changed diet. Therefore, it is postulated that their rib ratios had not yet caught up to the increases evident in their dentine isotopic profiles.

__Table 6. Individual isotopic differences between the average $\delta^{13}C$ and $\delta^{15}N$ values of the final three dentine collagen increments and the bulk rib bone values, the average differences per site, and the overall differences.__ The averages are shown ± 1 standard deviation. A negative value indicates that the isotopic ratio of the rib plots below the average dentine

			Individual Differences		**Average Differences per Site**		**Overall Average Differences**	
Site	**Individual**	**Lab Code**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**
	PC-37	1101	0.2	0.1				
	PC-42	1102	0.1	0.0				
Priory Close	PC-47	1103	-0.2	-0.3	-0.1 ± 0.3	-0.3 ± 0.3		
	PC-52	1104	-0.5	-0.7				
	PC-59	1105	-0.1	-0.6			-0.1 ± 0.3	-0.5 ± 0.5
	CP-7	1106	-0.4	-0.9				
	CP-10	1107	-0.1	-1.1				
Clavering Place	CP-11	1108	-0.2	-1.0	-0.1 ± 0.3	-0.7 ± 0.5		
	CP-17	1109	-0.3	-0.7				
	CP-19	1110	0.4	0.2				

sections. Note the larger negative differences in $\delta^{15}N$ values for the Clavering Place site.

3.3 DISH

The individuals from Priory Close associated with DISH (Sks. PC-42, PC-52, and PC-59) all have bulk bone collagen $\delta^{15}N$ values that plot above the means of the sites, while Sks. PC-52 and PC-59 also have $\delta^{13}C$ values that plot above the mean (Figure 8). For Sks. PC-52 and PC-59, this indicates that these individuals were consuming a diet with relatively more animal and marine protein than the others at the site. Because Sk. PC-42 had a higher $\delta^{15}N$ but a slightly lower $\delta^{13}C$, this may indicate that this individual consumed relatively more freshwater fish compared to the others at the site. While this difference from the mean is not statistically significant, the result of Sk. PC-59 (the only individual who could be diagnosed with DISH) nevertheless upholds the isotopic pattern of individuals affected by DISH reported in Section 1.4, namely that their $\delta^{13}C$ and $\delta^{15}N$ values tend to plot above the means of the site.

It is interesting to note that the individuals associated with DISH (Sks. PC-42, PC-52, and PC-59) also have the highest mean $\delta^{15}N$ dentine collagen values for the site (Table 4). This may indicate that the link with DISH is not so much a high protein diet later in life, but rather a high protein diet during youth, or perhaps a high protein diet that begins in youth and continues throughout life. Assuming that a high $\delta^{15}N$ value is indicative of a rich diet and therefore a potential marker of obesity, this observation supports the findings from clinical studies that have demonstrated that DISH patients weighed more at a young age (Mata *et al.* 1997; Kiss *et al.* 2002), suggesting that obesity at an early age and later in life is a strong risk factor for DISH (Kiss *et al.* 2002). One individual from Clavering Place (Sk. CP-10) also has a high mean $\delta^{15}N$ dentine collagen value of 14.0 ± 0.7‰. Keeping in mind that the prevalence of DISH increases with age (Vaishya *et al.* 2017), it is interesting to postulate whether this individual, with an estimated age-at-death of 26-35 years (Caffell and Newman 2016), would have developed the condition had he survived to an older age, as had those individuals associated with DISH from Priory Close who were all estimated to be at least 36 years of age at death (Caffell 2007). Future investigations into the link between diet and DISH should therefore examine dietary isotopic profiles during youth to determine whether there is consistent evidence showing a high-protein diet during childhood or adolescence in individuals diagnosed with DISH.

3.4 The Wider Context

The consumption of marine protein seen in Figure 8 lends further support to the diachronic trend of an increase in the consumption of marine protein noted during the Later Medieval period in England and Scotland discussed in Section 1.2. When plotted with the mean $\delta^{13}C$ and $\delta^{15}N$ values of previously published sites that are temporally and geographically related, Priory Close and Clavering Place uphold the pattern of the positive association of $\delta^{13}C$ and $\delta^{15}N$, plotting slightly above the others in regard to both $\delta^{13}C$ and $\delta^{15}N$ values, excepting Portmahomack (Figure 10). The position of the two sites on the plot suggests that the individuals at Priory Close and Clavering Place were consuming a relatively greater component of marine protein than the individuals at the sites plotting below them. It should be cautioned that this greater consumption of marine protein could be due to sampling bias. Judging from the dentine collagen isotopic profiles of the individuals analyzed as well as the male demographic profile, it seems likely that the individuals may indeed have been friars. The other religious sites on the plot all included lay individuals as well, with the exception of the high-status individuals from Whithorn. It could therefore be that were it possible to exclude the values of the lay individuals at these sites, the $\delta^{13}C$ and $\delta^{15}N$ values would increase toward those values of the presumed friars at Priory Close and Clavering Place.

The specific mean faunal and human data for each site, listed in approximately chronological order, is shown in Table 7. This table highlights several details that should be noted. Wharram Percy, the site that appears below the others as an outlier in Figure 10, is the site dating from the earliest time period, and it is the only site presumed to contain only ordinary peasant burials (Fuller *et al.* 2003). The apparent lack of marine protein consumption in the individuals at this site may be due to its earlier time period compared to the rest of the sites, or it may be due to a lack of higher status individuals here. Interestingly, excluding Wharram Percy, Whithorn Cathedral Priory and Portmahomack, both in Scotland, show the smallest differences between their mean human and faunal $\delta^{15}N$ values, despite Portmahomack plotting above all the other sites. These small differences can be attributed to these sites' coastal locations and thus probable salt marsh grazing of the animals (Müldner *et al.* 2009; Curtis-Summers *et al.* 2014), since salt marsh grazing and proximity to the sea have been shown to elevate $\delta^{15}N$ levels (Richards *et al.* 2006; Britton *et al.* 2008). The other sites have differences between

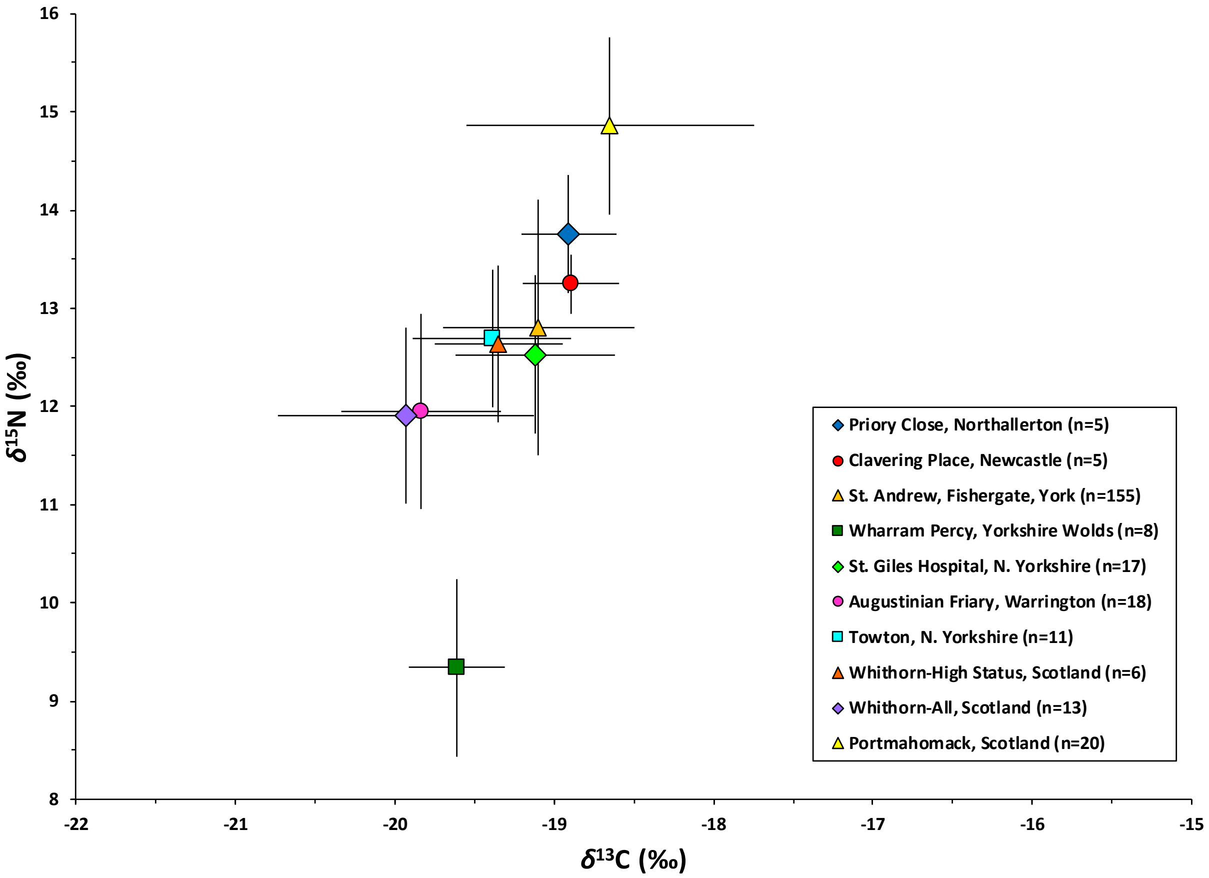

Figure 10. Mean $\delta^{13}C$ and $\delta^{15}N$ values of sites temporally and geographically related to Priory Close and Clavering Place. *All means are shown with error bars indicating ±1 standard deviation. Data for plot taken from Müldner and Richards (2007b); Fuller et al. (2003); Müldner and Richards (2005); Müldner et al. (2009); and Curtis-Summers et al. (2014).*

Table 7. Differences in mean faunal and human δ^{13}C and δ^{15}N values from sites illustrated in Figure 10. *Data from sites temporally and geographically related to Clavering Place and Priory*

		Mean Baseline Faunal Data						Difference Between Human and Faunal Means			
		Herbivore		Omnivore		Mean Human Data		Herbivore		Omnivore	
Site and Burial Type	**Time Period**	**δ ^{13}C (‰)**	**δ ^{15}N (‰)**	**δ ^{13}C (‰)**	**δ ^{15}N (‰)**	**δ ^{13}C (‰)**	**δ ^{15}N (‰)**	**δ ^{13}C (‰)**	**δ ^{15}N (‰)**	**δ ^{13}C (‰)**	**δ ^{15}N (‰)**
Wharram Percy, Yorkshire[a] *ordinary peasants of parish*	10th to 16th century AD	-21.8 ± 0.3	5.4 ± 1.0	-21.3 ± 0.4	6.6 ±1.7	-19.6 ± 0.3	9.3 ± 0.9	2.2	3.9	1.7	2.7
Whithorn Cathedral Priory, Scotland[b]											
high status (presumed bishops and priests)	11th to 14th century AD	-22.0 ± 0.3	7.6 ± 1.4	-21.1 ± 0.8	10.5 ± 2.1	-19.4 ± 0.4	12.6 ± 0.8	2.6	5.0	1.7	2.15
all (including high status, lay benefactors, and others of unknown rank)	11th to 14th century AD	-22.0 ± 0.3	7.6 ± 1.4	-21.1 ± 0.8	10.5 ± 2.1	-19.9 ± 0.8	11.9 ± 0.9	2.1	4.3	1.2	1.45
St. Giles Hospital, N. Yorkshire[c] *likely inmates of rural hospital but also 2 presumed priests and a patron*	12th to 15th century AD	-21.8 ± 0.6	5.5 ± 1.2	-21.3 ± 0.4	6.9 ± 1.4	-19.1 ± 0.5	12.5 ± 0.8	2.7	7.0	2.2	5.6
St. Andrew, Fishergate, York[d] *burials in Gilbertine Priory*	13th to 16th century AD	-21.5 ± 0.4	5.5 ± 1.0	-21.5 ± 0.5	8.1 ± 1.3	-19.1 ± 0.6	12.8 ± 1.3	2.4	7.3	2.4	4.7
Clavering Place, Newcastle *presumed friars*	13th to 16th century AD	-22.0 ± 0.2	5.9 ± 1.5	-21.3 ± 0.3	9.6 ± 1.3	-18.9 ± 0.3	13.2 ± 0.3	3.1	7.3	2.4	3.6
Augustinian Friary, Warrington[c] *friars and lay benefactors*	13th to 17th century AD	-21.8 ± 0.6	5.5 ± 1.2	-21.3 ± 0.4	6.9 ± 1.4	-19.8 ± 0.5	12.0 ± 1.0	1.2	6.5	1.5	5.1
Priory Close, Northallerton *presumed friars*	14th to 16th century AD	-22.0 ± 0.2	5.9 ± 1.5	-21.3 ± 0.3	9.6 ± 1.3	-18.9 ± .3	13.8 ± 0.6	3.1	7.9	2.4	4.2
Towton, N. Yorkshire[c] *mass grave suggestive of professional soldiers*	15th century AD	-21.8 ± 0.6	5.5 ± 1.2	-21.3 ± 0.4	6.9 ± 1.4	-19.4 ± 0.5	12.7 ± 0.7	2.4	7.2	1.9	5.8
Portmahomack, Scotland[e] *population of parish including men, women, and children*	15th and 16th century AD	-22.0 ± 0.0	9.4 ± 0.8	-21.4 ± 0.4	11.9 ± 0.1	-18.7 ± 0.9	14.9 ± 0.9	3.3	5.5	2.7	3.1

a: Site information, time period, and human data taken from Fuller *et al.* 2003; human data includes only 8 values published in Fuller *et al.* 2003 out of 28 adults initially reported in Richards *et al.* 2002; faunal data taken from Müldner and Richards 2005.

b: Data taken from Müldner *et al.* 2009

c: Data taken from Müldner and Richards 2005

d: Faunal data taken from Later Medieval samples from Müldner and Richards 2007a; human data taken from Müldner and Richards 2007b

e: Data taken from Period 4 humans and faunal samples from Curtis-Summers *et al.* 2014

Close calculated from values in published literature.

mean human and faunal $\delta^{13}C$ and $\delta^{15}N$ values that are higher than an expected trophic shift, thus providing evidence for consumption of marine protein at these sites.

The main limitation of this study is its small sample size. With such a small sample, it is impossible to obtain statistically significant results. Although general patterns and trends have been observed here, no solid conclusions can be drawn from them until a larger sample is analyzed to confirm them.

Another major limitation of this project is differentiating between burials of religious individuals versus those of lay benefactors. Friaries in particular gained popularity as burial places from about the mid-13th century onward, not only for wealthy patrons but also for other lay people (Postles 1996). Due to the uniformity of Christian burials, it is virtually impossible to make a distinction between the two, although in some rare cases clues might be left to help identify the religious in a monastic cemetery. For example, at the Augustinian friary in Hull, at least 33 burials contained similar belt buckles which has been interpreted as potentially being associated with the monastic habit (Gilchrist and Sloane 2005, 84). Even this type of evidence is no guarantee in identifying the religious in a cemetery, however, as it is documented that the request for burial was often accompanied by the desire to be buried in the habit of the order (Bruzelius 2007). Because of this ambiguity, it is impossible to be confident that the individuals analyzed in this project were friars rather than lay patrons. This does impact on the confidence of the conclusions drawn regarding dietary change. As noted in Section 1.2, an increase in fish consumption does not necessarily indicate a shift in diet when entering a religious order. Perhaps, for example, males in this region and time period consumed greater quantities of fish during their adolescence and early adulthood regardless of entering a mendicant order. Ideally, this study would be repeated on two samples of individuals from the same region and time period: one consisting of known religious individuals, and the other consisting of known wealthy laymen. Only then would it be possible to prove conclusively that religious individuals indeed ate a diet containing more fish than laymen.

Another limitation involves ambiguity regarding dating of the individuals recovered from Clavering Place. Previous excavations at the site led Harbottle (1968) to believe that the chapter house was built during the Carmelite occupation. Contrary to this, however, two of the individuals from the chapter house were radiocarbon-dated to the 13th Century (c. 1220–1295 cal AD, both with 95.4% probability), the time period coinciding with the occupation of the Friars of the Sack (Claydon 2016). The individuals recovered from the southeastern cemetery, however, were not dated, so it is difficult to associate them with either the Friars of the Sack or the Carmelite occupation with certainty. It is therefore impossible to be certain of the religious order of the individuals analyzed from Clavering Place, thus preventing reliable inferences about potential differences between the two religious orders.

Additionally, a limitation noted in Section 3.1 is the variability of the formation of the third molar. Despite this, multiple studies have concluded that third molar root formation can nevertheless be used as a reliable method for chronological age estimation (e.g. Gunst *et al.* 2003; De Salvia *et al.* 2004; Kasper *et al.* 2009; Zandi *et al.* 2015). Therefore, while this inherent variability prevents an exact estimation of an individual's age at any given isotopic shift in diet, the third molar still encompasses the expected age range for entrance into a friary.

4 Conclusions

The δ^{13}C and δ^{15}N profiles of all individuals from both sites studied increased from the beginning of the formation of the third molar at c. 8.5 year to its completion at c. 23.5 years indicating a shift during adolescence from a largely terrestrial mixed diet to one that contained a significant amount of animal and marine protein. However, the observed dietary change does not appear to have taken place at the same age in all individuals. Assuming these individuals were friars, the results show that a detectable isotopic change in diet occurs upon entry into a religious order which supports the historical evidence, but they do not show a consistent age at which this occurred.

The mean rib collagen δ^{13}C and δ^{15}N values – representing diet prior to death – at Priory Close and Clavering Place were largely indistinguishable and in line with published data from other later medieval religious sites in northeastern England. However, individuals exhibiting skeletal pathology associated with DISH were found to have individual δ^{13}C and δ^{15}N values that were elevated above the means for each site and may provide evidence for a higher level of protein consumption not only as adults, but also during youth.

Overall, this study provides evidence for a shift in diet experienced by members of religious orders during adolescence and lays the foundation for future studies of dietary changes at different religious institutions.

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